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A COMPREHENSIVE ANALYSIS IN PID TUNING WITH SOFT COMPUTATION IN PAPER INDUSTRY

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ABSTRACT

In this paper, Particle Swarm Optimization algorithm (PSO) method has been applied on a moisture control system for auto tuning (PID) parameters. Proportional – Integral – Derivatives control scheme is used to provide efficient and quiet easier in control engineering applications. Most of the PID tuning methods are used in manually which is difficult and time consuming. PSO Algorithm which leads to improved efficiency of tuning of process. The proposed algorithm is used to tune the PID parameters and its performance has been compared with Fuzzy logic techniques. Compare to fuzzy logic technique dynamic performance specfications such as rise time, peak time and peak overshoot optimal values produced by PSO. The plant model represent by the transfer function is obtained by the system identification tool box.

Keywords: paper machine, PID controller, fuzzy logic, particle swarm optimization algorithm, moisture.

INTRODUCTION

A paper machine is functional to produce the paper sheet followed by removing water content from it. The paper machine constitutes three divisions namely, the wire section, press section and drying section [1-5]. At the wire section when the stock encounters the head box there will be the more presence of 1% of fibre (or) less. On the wire, the obtained low viscous mix is dispensed via a long slice. Upon its travelling on the wire the gravitational forces (or) the section from underneath drain most of the water content. Then due to the absence of water, the cellulose fibre begins to stick to one another by hydrogen bond to form the paper web. Then, it enters the press section with dry solid content of about 20%. The new sheet produced is pressed between rotating steel roles and the water is displaced. Further, few press nips are carried out as a outcome web with 50% of solid content approximately enters the drying section, then to dryer cylinders. They dry the paper when it passes by heating it internally with stream. Towards the end the paper is wound upon a big roll and removed from the paper machine with moisture content of 5-10%. Drying section besides removing less than 1% of water content from original stock, consumes more energy (i.e.) 2/3 of total energy requirement in paper making. Hence it become the most expensive part of machine in terms of energy use per kg to removed water. It also affects many significant physical properties of the product like paper sheet elasticity, twist and curl. Moisture content variations affect the units after processing like calendaring, packaging line (or) customers printing press. Hence the moisture content is monitored and the measured value is checked with the specified limits and on deviation the product is rejected. Uniform moisture content and its stability ensures low rejection and high production rates. Modern paper machine produce 1000tons of paper per day, 0.1% reduction of moisture lend 365 tons of raw material per year. The production costs 500 euro per ton which is a large economical saving. Moisture increment will reduce the energy usage. Machine speed is increased to enhance the production. Hence to achieve maximum production higher speed operation is carried out with desired control constraints moisture reduction will increase the speed without attaining maximum steam pressure. State transition time is reduced with the help of well-tuned moisture control system. During the time of grade change (state transition), moisture feedback loop is set off and open loop process is set on (feed forward). The model errors make the deviation from set point in feed forward loop once the feedback is set on again. So, this makes the moisture control more significant in final phase of the grade change and shorter grade change time in turns directly correlated to economic profit.

MACHINE DIRECTION (MD) MOISTURE CONTROL

The quality control system (QCS) is divided in two separate dimensions, the machine direction control (MD) and the cross direction control (CD).The conventional technique is to measure the MD and CD signals by scanning the sheet with a single sensor. The sensor is mounted in a scanner platform, where it moves back and forth in the cross direction. See Figure-2. The primary mechanism today for the control of the moisture MD variations is the dryer steam pressure. The moist paper can be led around a single large steam heated cylinder, called Yankee cylinder (mainly used for the drying of tissue) or a large number of steam heated cast iron cylinders in series (commonly called cans), called multi-cylinder drying. The purpose of the steam and condensate system is to provide a sufficient amount of steam to the dryers and to handle the condensed steam.

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The cylinders in a drying section are divided in separate dryer groups, normally between five and ten groups. The steam pressure in the different dryer groups can then be controlled individually go obtain the desired pressure profile through the drying section, from the first group to the last one. Since the steam inside the cylinder can be regarded as saturated because of the continuous condensation at the cylinder wall, there is a direct correlation between the steam pressure and steam temperature and you could also talk about a temperature profile. For most paper grades, dryer steam pressure is increased gradually for drying capacity and run ability reasons.

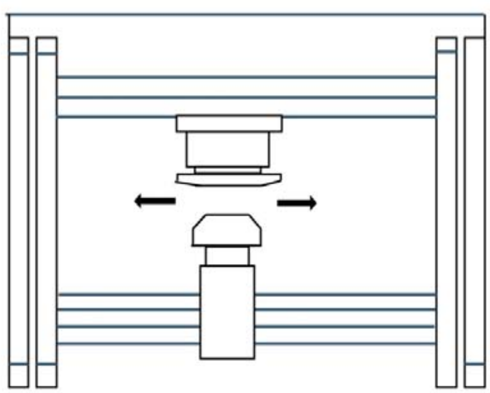

Figure-1. Quality control scanner moves the sensor back and forth across the sheet by courtesy of ABB Ltd.

MATERIALS AND METHODS

Design of fuzzy controller

Fuzzy logic controllers is the one of the intelligent controllers which is very popular now-a-days. Fuzzy logic control is derived from fuzzy set theory introduced by Zadeh in 1965. The human brain can reason vague information and uncertainties which machines cannot do. Unlike machines human beings have common sense that enables them to do reason the things which are particularly true [6-9]. Fuzzy logic helps a machine to understand such vague concepts, in fuzzy set theory, the transition between memberships can be gradual. Consequently, boundaries of fuzzy sets can be vague and ambiguous, making it applicable for approximate systems. Fuzzy logic uses linguistic variables instead of numeric variables. The process of converting a numerical variable (real number or crisp variables) into a linguistic variable (fuzzy number) is called fuzzification.In the present work, error and change in error of speed are fuzzified. The Seven linguistic variables using triangular membership function is used as in Figure-2, Figure-3 and Figure-4.

Fuzzy rules

de	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	Z
NM	NB	NB	NB	NM	NS	Z	PS
NS	NB	NB	NM	NS	Z	PS	PM
Z	NB	NM	NS	Z	PS	PM	PB
PS	NM	NS	Z	PS	PM	PB	PB
PM	NS	Z	PS	PM	PB	PB	PB
PB	Z	PS	PM	PB	PB	PB	PB

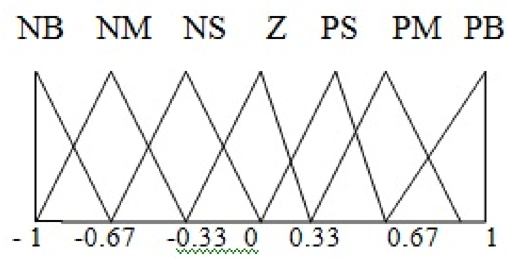

Figure-2. Error (input).

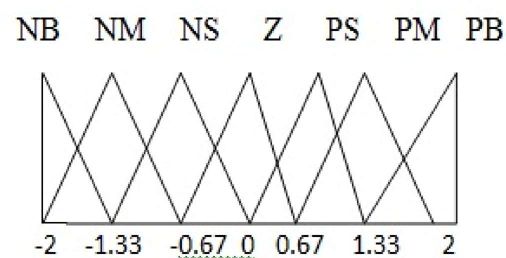

Figure-3. Change in error (Input).

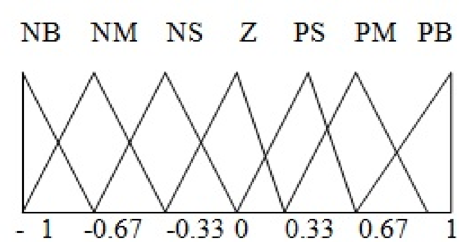

Figure-4. Control output.

TUNING of PID using PSO

This algorithm proposed by Eberhart and Kennedy uses a 1-D approach for searching within the solution space [10]. For this study the PSO algorithm will be applied to a 2-D or 3-D solution space in search of optimal tuning parameters for PID, PI and PD control..Consider position $X_{i,m}$ of the i-th particle as it traverses a n-dimensional search space. The previous best position for this i-th particle is recorded and represented as pbest $_{I,n}$.The best performing particle among the swarm population is denoted as gbest $_{I,n}$ and the velocity of each particle within the n-dimension is represented as $V_{i,n}$.The

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new velocity and position for each particle can be calculated from its current velocity and distance respectively. So far (p_{best}) and the position in the d-dimensional space. The velocity of each particle is adjusted in accordance with its own flying experience. In the proposed PSO method each particle contains three members P,I and D which means that the search space has three dimension and particles must 'fly' in the three dimensional space. The technical specifications of paper machine are shown in Table-1.

Components	**Technical specifications**
DCS System AC 450 Controller	AC 450 Controller AI - 4 - 20 MA, AO - 4 - 20MA AMPL – Programming
Quality Control Scanner	Moisture – IR Sensor Output- (4 - 20 MA) Honey Well make
Control Valve	Size:6'', Pneumatic actuated Type: Air to Open
I/P Converter	Input- 4 - 20 MA; Output- 0 - 6 Bar
Dryer	43 Cylinders,5 groups; Material-Milled Steel
Steam Pressure	3.5 Bar to 4.5 Bar
Steam Temperature	150C to 180C
Day Production & Machine Speed	350 MT & 700M

RESULTS AND DISCUSSIONS

A transfer function to validate the process is obtained with the real time data using Matlab system identification toolbox. The tuned values through the traditional, as well as the proposed techniques, are analysed for their responses to a unit step input, with the help of Matlab simulation. The classical methods such as Ziegler Nichol's method are employed to find out the values of Kp, Ki and Kd. If the classical methods cannot be able to provide the optimal solution, they give the initial values or boundary values needed to start the soft computing algorithms. In the closed-loop system it is considered with unity feedback and a PID controller is placed. The modeled system is represents in the equation (1)

$$\frac{0.978\ \exp(-1.976\ s)}{5.18\ s^2 + 5.016\ s + 1} \quad (1)$$

To control the plant model the Fuzzy and PSO parameters are used to verify the time domain specifications. Fuzzy controller tuning lead to a large settling time, overshoot rise time and steady state error of the controlled system. PSO based tuning method have been proved their excellence in giving better results by improving the steady state characteristics and performance indices, improving the steady state characteristics and performance indices.The output response of fuzzy logic controller and PSO are Figure-5 and Figure-6, respectively.

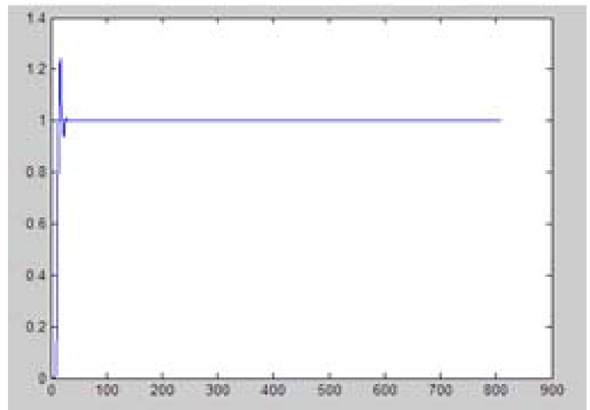

Figure-5. Response of fuzzy controller.

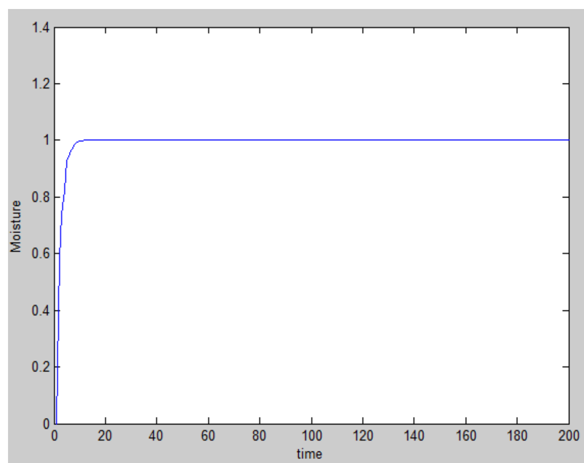

Figure-6. Response of PSO controller.

CONCLUSIONS

In this paper, two different methods regarding the tuning at Fuzzy logic controller and PSO has been presented. Fuzzy logic controller method gives the approximate value of any response not the appropriate or exact value and it is having one more disadvantage that the rise time and settling time will be more. To obtain the better performance it is necessary to reduce both the rise time and settling time concurrently, by using FLC, the process will not get desire value. PSO Algorithm is used to overcome this problem. By using PSO the whole overshoot was successfully eliminated, as well as both settling time and rise time was reduced. The simulation results shows that compared to Fuzzy, PSO has better response curve for time domain specification.

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